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Research of the drawing of bars plate in the refiners

S N Vikharev^{1,3} and VA Morkovin²

¹ Department of technical mechanics and technologies machine industry, Ural State Forest Engineering University, 37, Siberian tract, Ekaterinburg, 620100, Russia

² Department of industrial transport, construction and geodesy, Voronezh State University of Forestry and Technologies named after G.F. Morozov, 8, Timiryazeva, Voronezh, 394087, Russia

³ E-mail: cbp200558@mail.ru

Abstract. Object of research of article is the drawing of bars plate in the refiners at refining of chips and wood pulp. On the basis of the theory of contact interaction of bars influence of the drawing of plate on characteristics of contact processes is investigated. The friction coefficient between plate decreases at increase in density of contact of bars. At increase in an angle of crossing of bars rotor and stator and refining of pulp with concentration up to 6% the coefficient of friction decreases. At increase in an angle of crossing of bars chips and pulp with concentration over 10% the coefficient of friction increases. Therefore it is recommended to increase the angle of crossing of bars rotor and stator at refining of pulp of low concentration, and at refining of pulp of concentration over 10% and chips - to reduce, up to a radial arrangement.

1. Introduction

Refining of chips and fibrous materials is usually made in the refiners. These machines have low efficiency and very much power-intensive [1,2]. The principle of action of mills is based on contact action of bars plate on a pulp. Many firms and authors offer various drawings of bars plate which depends on factors of process refining [3-8]. Now the drawing of bars plate, as a rule, is defined experimentally proceeding from maximum efficiency of process of refining. Understand achievement of the required gain of characteristics of the ground pulp at the minimum power consumption as efficiency of this process. In Russia scientists under the leadership of Y.D. Alashkevich do attempts to connect the drawing of plate with process of refining [9,10], similar works and abroad are known [11-17]. However these researches have semi-empirical and fragmentary character.

Article purpose - to investigate the drawing of bars plate of mills at refining of chips and fibrous materials by means of the theory of contact.

2. Methods and materials

Now the theory of contact action of bars plate which connects properties of the ground pulp with refining process factors is developed. On the basis of this theory the coefficient of friction and thermal emission at refining are investigated [18,19]. The scheme of contact interaction of bars plate is submitted in the figure 1, a [20]. The drawing of bars plate is described by means of the Hevisayda function

$$f(x, z) = h_0/2 + \sum_{j=1}^n (1 - h_0/h_{pj}) h_{pj} \Delta f x_j z_j, \quad x \in (0, l), \quad z \in (0, r)$$



where $\Delta\Gamma x_j, z_j = \Gamma(x, z - x_j, z_j) - \Gamma[x, z - x_j, z_j - c_j, l_j]$, $\Gamma(x, z)$ - single function Hevisayda, x_j, z_j - the coordinate of point of the beginning j bar, c_j, l_j - respectively width and length of j bar, h_0 - thickness of plate, h_{rj} - height of j bar, n - number of bars.

For the platform of contact of bars [21]

$$\hat{P}_e = 2 \sum_{j=1}^N \Delta \hat{z} \int_{-\hat{a}_j}^{\hat{b}_j} \hat{p}_j(\hat{x}, \hat{z}_j) \cos \varphi(\hat{x}) d\hat{x}$$

$$\hat{T}_d = 2 \sum_{j=1}^N \Delta \hat{z} \int_{-\hat{a}_j}^{\hat{b}_j} \hat{p}_j(\hat{x}, \hat{z}_j) \sin \varphi(\hat{x}) d\hat{x},$$

where \hat{P}_e, \hat{T}_d - dimensionless forces operating on plate bars, $\hat{p}_j(\hat{x}, \hat{z}_j)$ - dimensionless contact pressure between bars.

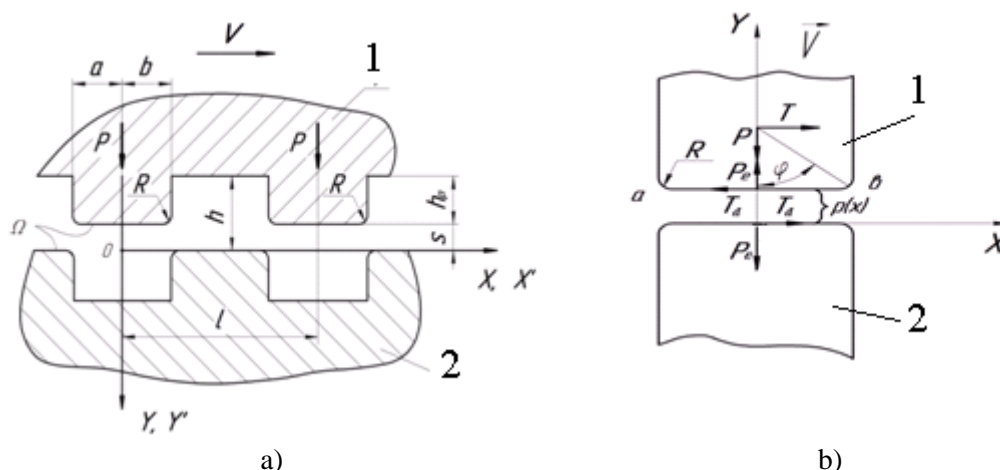


Figure 1. Action of bars at refining of fibrous materials: a) - scheme; b) - forces operating on bars; 1- rotor; 2 - stator.

The friction coefficient μ at refining can be written down as

$$\mu = \hat{T}_d / \hat{P}_e.$$

Fibrous material and chip are modeled at liquid friction of rotor and stator by model of viscoelastic body of Maxwell - Thomson, at boundary friction - model of an elastic body Guk [19].

3. Results and discussion

Contact characteristics of action of plate on the ground material depend on the following sizes [20]:

1. Introductions of bars in pulp α/c , α - reduction of an inter bar gap at load of
2. bar P , c - width of bars plate;
3. Characteristics of load of fibrous material $\hat{P} = \frac{2P}{c^3} s / E^*$, where s - thickness of fibrous material between bars plate, E^* - module of elasticity of model of Maxwell - Thomson;
4. Relations of time of an after-effect and relaxation of fibrous material;
5. Deborah's numbers ξ which describes refining process $\xi = T\sigma V / a_H$, a_H - size of platform of contact, V - speed of movement of bars, $T\sigma$ - pulp relaxation time;

6. Contact density c / l , l - step of bars (figure 1,b). It should be noted that density of contact of bars at refining changes with plate frequencies.

The amount of contact of plate can be determined as [20]

$$a_H = 3 \sqrt[3]{\frac{3Pc}{4E^*}}$$

Parameters of model of fibrous material depend on a look and concentration of pulp. The dependence of $a_H = (lg P)$ on the schedule represented in the figure 2. Parameter a_H depends on properties of the ground material and load of bar P . Maximum amount of contact of plate rotor and stator

$$a_{H\max} = \frac{c}{\cos \frac{\beta}{2}}$$

where β - angle of crossing of bars plate. The amount of contact of plate can also increase due to clogging of inter bar flutes of plate fibrous material [1]. Amplitude of the pulse pressure arising when crossing bars depends on properties of the ground material and introduction in a fibrous pulp (figure 3). The schedule in the figure 3 is received in the program Matlab environment for model of sulphatic cellulose by concentration 30-35%, $c = 4 \cdot 10^{-3}$ m, speeds of movement of bars rotor concerning stator bars $V = 90$ m/s and $l/c = 2.5$. At big speeds of movement V there is so-called "emersion" of bars. It is characteristic of all viscoelastic pulps. At very small speeds of movement ($V \rightarrow 0, \zeta \rightarrow 0$) introduction of bars in pulp does not depend on density of contact of bars plate. It occurs because the ground material completely is restored before the following influence of bar. At the high speed of movement of bars the relation c/l considerably influences process of refining and contact characteristics. The gap between plate bars s at identical loading decreases at increase in step of bars l . It also well is explained by the theory of contact. Deborah's number at refining of various materials with parameters of $V = 150$ m/s is shown $a_H = 3 \cdot 10^{-3}$ m. Deborah's number at refining from gap between plate of rotor and stator, speed of movement and the angle of crossing of bars is displayed in figures 4,5.

Table 1. Deborah's number at refining of fibrous materials.

Fibrous material	Wood	Cellulose concentration 1-30%	Cellulose air-dry
Deborah's number	$(2.5-24.0)10^5$	8.5-32.0	$(5.1-6.2)10^5$

Plate frequencies [18], i.e. frequencies of crossing of bars plate, in the modern refiners reach tens kilohertz. These frequencies increase from the center to the periphery of plate [22,23]. The dependence of coefficient of friction on the angle of crossing of bars plate is presented in the figure 6.

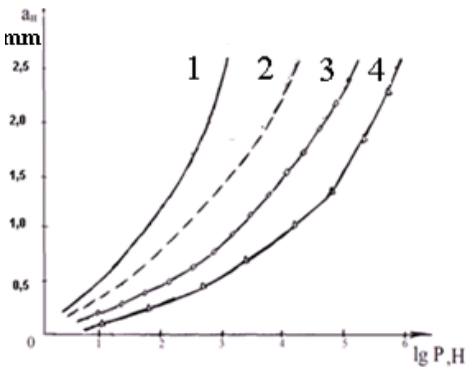


Figure 2. Platform size contact of bars depending on loads of bars: 1.2 - $E^* = 1.2 \cdot 10^5$ Pa; 3.4 - $E^* = 12.1 \cdot 10^5$ Pa; 1.3 - $c = 0.005$ m; 2.4 - $c = 0.002$ m.

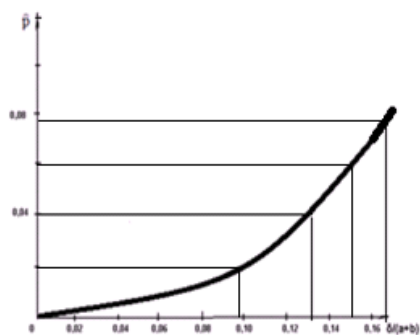


Figure 3. Amplitude of contact pulse pressure between bars depending on introduction of bars in pulp.

The friction coefficient between rotor and stator μ the bar refining machine depends on the following factors: look and concentration of the ground pulp; Deborah's number and drawing of bars plate. This coefficient decreases at increase in density of contact c/l . When determining coefficient of friction μ it is also necessary to consider hydrodynamic processes in flutes of plate and their filling with pulp. It is necessary to consider that at decrease in coefficient μ the power consumption of the bar refining machine decreases. The angle of crossing of bars plate of rotor and stator β significantly influences friction coefficient between plate. At increase β from 0 to 45° and refining of pulp of concentration up to 6% the coefficient β decreases (to 6%) from 0.18 till 0.11. At chips refining increase in an angle of crossing β from 0 to 45° coefficient of friction β increases from 0.45 till 0.62.

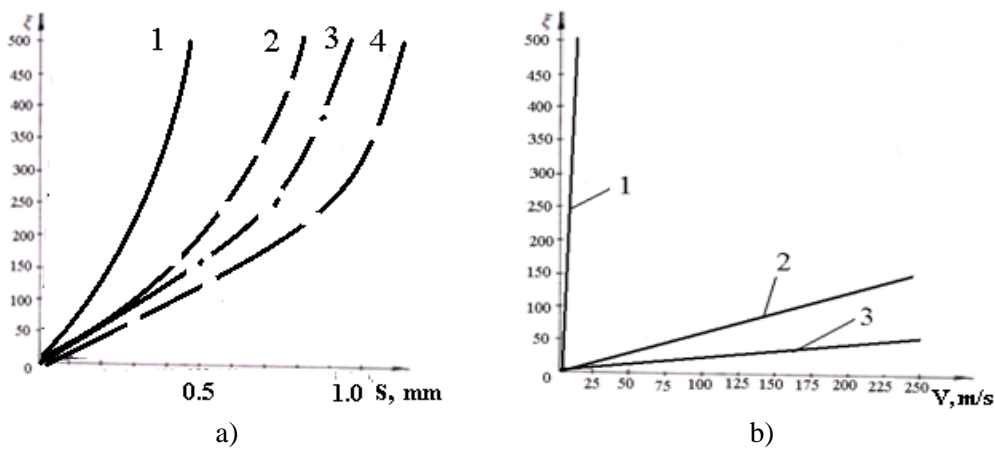


Figure 4. Deborah's number depending on variable factors: a) - gap between bars ($V = 120$ m/s); b) - speeds of movement of bars ($a_H = 3 \cdot 10^{-3}$ m); 1 - steamed pine chips concentration 45%; 2 - cellulose sulphatic concentration 15%; 3 - same concentration 5%.

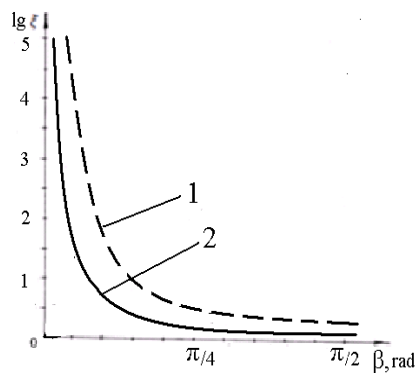


Figure 5. Deborah's number at refining from corner of crossing of bars plate ($a_H = 3 \cdot 10^{-3}$ m, $V = 120$ m/s): 1 - pine chips concentration 5%; 2 - cellulose sulphatic concentration 3%.

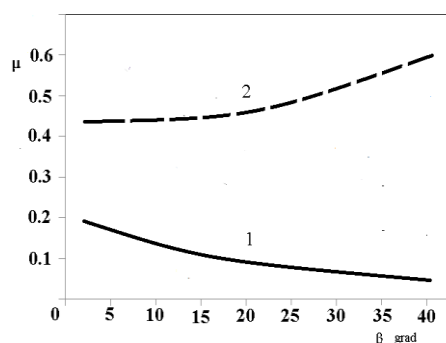


Figure 6. Friction coefficient from the angle of crossing of bars plate: 1- refining of pulp concentration up to 6%; 2- refining of chips.

Therefore it is recommended at refining of pulp of concentration up to 6% to increase the angle of crossing of bars β , and at refining of pulp of concentration over 10% and chips - to reduce, up to radial arrangement of bars when $\beta = 0^\circ$.

4. Conclusion

At a research of the drawing of plate at refining of materials the theory of contact of bars is used. The contact characteristics of processes arising at refining are investigated. These characteristics depend from:

- introductions of bars plate in fibrous material;
- parameters characterizing load of bars;
- Deborah's numbers at refining;
- density of contact of bars rotor and stator;
- properties of fibrous materials;
- properties of material of plate;
- type of friction between bars.

The drawing of plate influences the contact processes arising at refining of materials. The friction coefficient between bars plate of rotor and stator decreases at increase in density of contact. At increase in an angle of crossing of bars and refining of materials of concentration up to 6% the coefficient of friction decreases. At this corner and refining of chips and materials of concentration over 10% the coefficient of friction increases. Therefore it is recommended to increase the angle of crossing of bars at refining of pulp of low concentration, and at refining of pulp of concentration over 10% and chips - to reduce, up to its radial arrangement.

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